MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2016/2017

ETN3046 – ANALOG AND DIGITAL COMMUNICATIONS

(CE, EE, LE, ME, NE & OPE)

10 OCTOBER 2016
9:00 AM – 11:00 AM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 10 pages (including this cover page) with 4 Questions only and an appendix.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Modulation is a process of changing the carrier in proportion with the message signal. There are two types of modulation: analog and digital.
Differentiate between Amplitude Modulation (AM) and Amplitude Shift Keying (ASK).

[2 marks]

(b) Before modulation, a signal $x(t)$ has the spectral characteristic being expressed as $X(f) = \frac{j2\pi f}{1+j2\pi f} \cdot x(t)$ is further modified before being modulated. Determine $Y(f)$, the Fourier transform of $y(t)$, which is the result of modifying $x(t)$ based on the following relations:

(i) $y(t) = (-jt)\, x(t)$

(ii) $y(t) = \int_{-\infty}^{t} x(\tau) d\tau$

[3 + 3 = 6 marks]

(c)

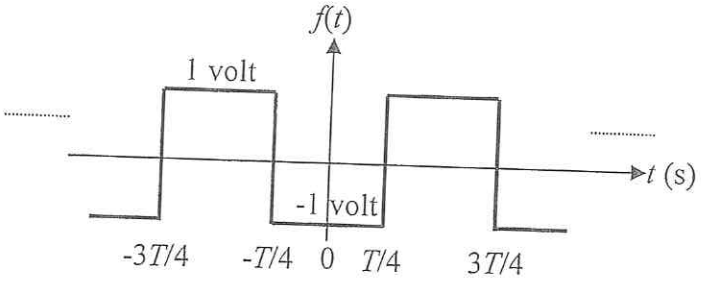

Fig. Q1.1

Fig. Q1.1 shows a periodical amplitude waveform that can be expressed in the form of trigonometric Fourier series as follows:

$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos\left(\frac{2\pi nt}{T}\right) + \sum_{n=1}^{\infty} B_n \sin\left(\frac{2\pi nt}{T}\right)$$

where

$$A_0 = \frac{1}{T}\int_T f(t)\ dt$$

$$A_n = \frac{2}{T}\int_T f(t) \cos\left(\frac{2\pi nt}{T}\right) dt$$

$$B_n = \frac{2}{T}\int_T f(t) \sin\left(\frac{2\pi nt}{T}\right) dt$$

T is the period of the waveform. Suppose $T = 2$ s. Find the values of A_0, A_n, and B_n for $n = 1, 2, 3, 4$.

[8 marks]

Continued ...

Question 1 (Continued)

(d) In an amplitude modulated (AM) wave, two signals are involved, i.e. the message signal $m(t) = \mathbf{37.5}\cos[(2\pi)(\mathbf{10}\times\mathbf{10}^3 t)]$ volts, and the carrier wave $c(t) = \mathbf{100}\cos[(2\pi)(\mathbf{500}\times\mathbf{10}^3 t)]$ volts. Suppose an AM wave of **75%** modulation is generated.

(i) Find the power developed across a load of **100** ohms due to this AM wave. [2 marks]

(ii) Find the power contained in the **carrier** and in the **sidebands**. [4 marks]

(iii) Sketch the power spectrum of this AM wave. [3 marks]

Question 2

(a) Fig. Q2.1 shows a single sideband (SSB) modulator. Assume that the message signal is given by $m(t) = A_m \cos(2\pi f_m t)$.

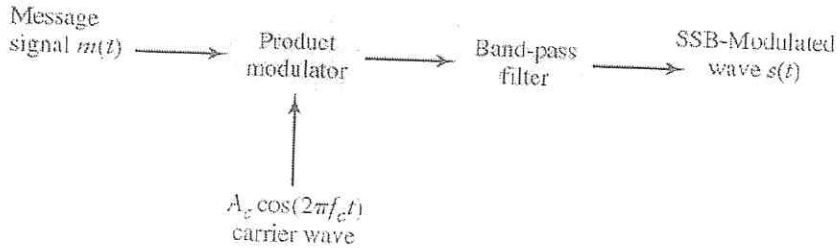

Fig. Q2.1

Determine the amplitude spectrum of the modulated signal $s(t)$ when the following is selected by the band-pass filter.

(i) Upper sideband (USB)

(ii) Lower sideband (LSB)

Sketch both of them and label the sketches clearly.

[4 + 4 = 8 marks]

Continued ...

Question 2 (Continued)

(b) Consider a frequency-modulated (FM) signal that is expressed as follows:

$$x(t) = A\cos\left[2\pi f_c t + B\int_0^t \cos(2\pi f_m \tau)d\tau\right]$$

where A and B are constants.
Write down the following expressions:

(i) Message signal, $m(t)$ [1 mark]

(ii) Instantaneous phase deviation, $\Delta\theta_i(t)$ [integration must be solved] [2 marks]

(iii) Instantaneous phase, $\theta_i(t)$ [1 mark]

(iv) Angular frequency deviation, $d\ [\Delta\theta_i(t)]\ /dt$ [differentiation must be performed] [2 marks]

(v) Instantaneous angular frequency, $\omega_i(t)$ [differentiation must be performed] [2 marks]

(vi) Instantaneous frequency, $f_i(t)$ [1 mark]

(c) A wideband frequency modulated (FM) signal is expressed as follows:

$$x(t) = 5\cos\{(2\pi)(10\times10^6 t) + 3\sin[(2\pi)(4\times10^4 t)]\}$$

The modulation index is 3. The values of the Bessel Function of the First Kind are listed in Table Q2.1.

(i) Find the carrier power, $P_{carrier}$. [3 marks]

(ii) Find the sidebands power, $P_{sidebands}$. [3 marks]

(iii) Determine the total power of the FM signal, P_{total}. [2 marks]

Table Q2.1: Table of the Bessel Function of the First Kind

	$J_n(\beta)$			
n	$\beta = 1.0$	$\beta = 2.0$	$\beta = 3.0$	$\beta = 5.0$
0	0.765	0.224	-0.260	-0.178
1	0.440	0.577	0.339	-0.328
2	0.115	0.353	0.486	0.047
3	0.020	0.129	0.309	0.365
4		0.034	0.132	0.391
5			0.043	0.261
6			0.011	0.131
7				0.053
8				0.018

Continued ...

Question 3

(a) (i) State the Nyquist sampling theorem. [2 marks]

(ii) Assuming instantaneous (ideal) sampling, briefly describe how does the spectrum of the sampled signal $m_s(t)$ differ from the spectrum of the original signal $m(t)$. [2 marks]

(iii) Figure Q3.1 shows the spectrum of a bandlimited signal $x(t)$. If $x(t)$ is instantaneously sampled at the Nyquist rate, sketch the spectrum of the sampled signal. [3 marks]

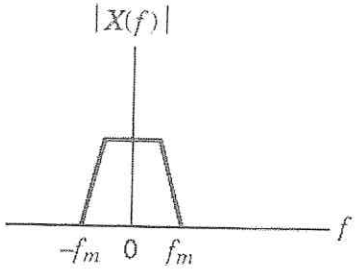

Figure Q3.1

(b) Given an audio signal with spectral components in the frequency band 300 Hz to 3,200 Hz, assume that a sampling rate of 8 kHz is used to generate a pulse code modulation (PCM) signal. The PCM signal is to be transmitted across a baseband channel and ultimately be received and decoded by a receiver. Design an appropriate PCM system by performing the following:

(i) Draw a block diagram of the PCM system, including the transmitter, channel and receiver. [3 marks]

(ii) Calculate the number of uniform quantiser steps needed and the channel null bandwidth required, assuming that the peak signal-to-noise ratio at the receiver output needs to be at least 32 dB and that polar non-return-to-zero signalling (no parity bits are used) with rectangular pulse is used.

Hint: $(S/N)_{dB} = 6.02n + \alpha$ where n is the number of bits in the PCM word, $\alpha = 0$ and 4.77 for average and peak SNRs respectively. The null bandwidth of a rectangular pulse is equal to its baud rate.

[3 marks]

(iii) If the audio signal is likely to have a large peak-to-average voltage ratio, suggest a possible enhancement method/technique that can be made to improve the performance of the PCM system. [2 marks]

Continued ...

Question 3 (Continued)

(c) (i) Briefly describe the working principle of a delta modulator (DM). [2 marks]

(ii) State and briefly describe with the aid of a diagram the two types of quantisation noise in a DM. [4 marks]

(iii) A DM is designed to encode speech signals limited to 3.4 kHz. The specifications of the modulator are as follows:

- Sampling rate = $10f_{Nyquist}$, where $f_{Nyquist}$ is the Nyquist rate for the speech signal.
- Step size $\Delta = 100$ mV.

The modulator is tested with a 1-kHz sinusoidal signal. Determine the maximum amplitude of this test signal required to avoid slope overload distortion. [4 marks]

Question 4

(a) (i) Briefly describe how intersymbol interference (ISI) arises in practical communication channels. State the impact of ISI on the performance of digital communication systems and the two major ISI mitigation techniques. [4 marks]

(ii) A quadrature phase-shift keying (QPSK) signal is designed to send data at a rate of 30 Mbits/s over a satellite channel with a bandwidth of 24 MHz. If the signal is equalised to have an equivalent raised cosine filter characteristic, determine the rolloff factor r required. With the rolloff factor r you obtained, determine the percentage of bandwidth saving if 16-PSK modulation is used for data transmission. [5 marks]

(b) A memoryless source generates one of six messages with probabilities of occurrence 0.35, 0.25, 0.15, 0.1, 0.08, and 0.07, respectively.

(i) Find the entropy of the source. [2 marks]

(ii) Apply the Huffman algorithm to this source to obtain the Huffman code for these messages. [6 marks]

(iii) Determine the efficiency of the Huffman code. [2 marks]

Continued ...

Question 4 (Continued)

(c) (i) State the error detection and correction capabilities of Hamming codes and cite their major application.

[2 marks]

(ii) Consider a (7,4) Hamming code with generator matrix

$$G = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Determine the codeword for the message bits 1 0 1 0.

[4 marks]

APPENDIX

Table of Fourier Transform Pairs

$x(t)$	$X(f)$
$\delta(t)$	1
$\delta(t-t_o)$	$e^{-j2\pi f t_o}$
1	$\delta(f)$
$e^{j2\pi f_o t}$	$\delta(f-f_o)$
$u(t)$	$\frac{1}{2}\delta(f)+\frac{1}{j2\pi f}$
$e^{-at}u(t)$	$\frac{1}{a+j2\pi f}$, for $a>0$
$e^{at}u(-t)$	$\frac{1}{a-j2\pi f}$, for $a>0$
$e^{-a\lvert t\rvert}$	$\frac{2a}{a^2+(2\pi f)^2}$, for $a>0$
$rect\left(\frac{t}{T}\right)$	$T\text{sinc}(fT)$
$\text{sinc}(2Wt)$	$\frac{1}{2W}rect\left(\frac{f}{2W}\right)$
$\Delta\left(\frac{t}{T}\right)$	$\frac{T}{2}\text{sinc}^2\left(\frac{fT}{2}\right)$
$W\text{sinc}^2(Wt)$	$\Delta\left(\frac{f}{2W}\right)$
$e^{-\pi t^2}$	$e^{-\pi f^2}$
$\cos(2\pi f_o t)$	$\frac{1}{2}\delta(f-f_o)+\frac{1}{2}\delta(f+f_o)$
$\sin(2\pi f_o t)$	$\frac{1}{2j}[\delta(f-f_o)-\delta(f+f_o)]$
$\text{sgn}(t)=\begin{cases}1 & t>0\\ -1 & t<0\end{cases}$	$\frac{1}{j\pi f}$
$\frac{1}{\pi t}$	$-j\,\text{sgn}(f)$

Table of Fourier Transform Properties

Let $x(t) \Leftrightarrow X(f)$, $x_1(t) \Leftrightarrow X_1(f)$ and $x_2(t) \Leftrightarrow X_2(f)$; and a, b, t_o and f_o scalar quantities.	
Linearity	$ax_1(t)+bx_2(t) \Leftrightarrow aX_1(f)+bX_2(f)$
Duality	$X(t) \Leftrightarrow x(-f)$
Scaling ($a \neq 0$)	$x(at) \Leftrightarrow \frac{1}{\lvert a \rvert} X\left(\frac{f}{a}\right)$
Time Shifting	$x(t-t_0) \Leftrightarrow X(f)e^{-j2\pi f t_0}$
Frequency Shifting	$x(t)e^{j2\pi f_0 t} \Leftrightarrow X(f-f_0)$
Modulation	$x(t)\cos(2\pi f_0 t) \Leftrightarrow \frac{1}{2}X(f-f_0)+\frac{1}{2}X(f+f_0)$
Time Convolution	$x_1(t) * x_2(t) \Leftrightarrow X_1(f)X_2(f)$
Frequency Convolution	$x_1(t)x_2(t) \Leftrightarrow X_1(f) * X_2(f)$
Time Differentiation	$\frac{d^n}{dt^n}x(t) \Leftrightarrow (j2\pi f)^n X(f)$
Frequency Differentiation	$(-jt)^n x(t) \Leftrightarrow \frac{d^n}{df^n}X(f)$
Time Integration	$\int_{-\infty}^{t} x(\tau)d\tau \Leftrightarrow \frac{X(f)}{j2\pi f}+\frac{1}{2}X(0)\delta(f)$
Frequency Integration	$x(t)u(t) \Leftrightarrow \int_{-\infty}^{f} X(\tilde{f})d\tilde{f}$

Useful Trigonometric Identities

$$\sin A \sin B = \frac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]$$

$$\cos A \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$$

$$\sin(A+B) = \sin A \cos B + \cos A \sin B$$

$$\cos(A+B) = \cos A \cos B - \sin A \sin B$$

$$\sin\theta = \frac{1}{2j}\left[e^{j\theta} - e^{-j\theta}\right]$$

$$\cos\theta = \frac{1}{2}\left[e^{j\theta} + e^{-j\theta}\right]$$

End of Paper